# TRACKING STUDIES FOR THE LHeC LATTICE

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## Abstract

The LHeC is a proposed upgrade to the LHC to provide electron-proton collisions and explore the new regime of energy and intensity for lepton-nucleon scattering. This experiment is expected to work alongside the HL-LHC to allow simultaneous nucleon-nucleon and lepton-nucleon collisions at separate interaction points. A first lattice design has been proposed that collides anticlockwise proton beam 2 with the electron beam. Different optical designs have been found providing a β* (β function in the interaction point ) of 10 cm using an extended version of the Achromatic Telescopic Squeezing (ATS) scheme, locating the inner triplet at different distances from the interaction point (L*). The aim of this work is to explore the stability of the beam by tracking particles on the lattice for these designs.


## Nominal Design

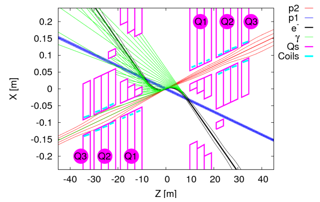


*Figure 1. Schematic view of the IR2 [1]*

The goal of the interaction region design is to collide proton beam 2 with the electron beam while proton beam 1 bypasses the interaction.

A first integration was achieved in [2] using the implementation of a new set of three quadrupoles closer to the interaction point (inner triplet) and the ATS technique [3]. This optical design located the inner triplet at L*=10 m and small β* in IP2 (for LHeC), IP1 and IP% (for HL-LHC). This values of β* being:

**β*=10 cm** in IP2 (LHeC)

**β*=15 cm** in IP1 And IP5 (HL-LHC)

Different optical designs with values L*= 10-20 m have been found in [4]. The chromaticity correction however was only achieved up to a value of L*=18 m., benefits in term of the synchrotron radiation reduction arise from increasing L*. This work intends to study these option in order to probe its feasibility in terms of stability of the beam.

## Objective

Doing tracking in Sixtrack to study the stability of the beam via the Dynamic Aperture (DA) and Frequency Map Analysis (FMA) for lattices with b=10 cm and different L*.

## Why?

Explore resonances and non-linear effects observed for a momentum spread δp=±0.001

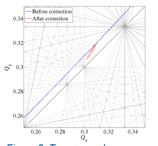


*Figure 2. Tune spread over a momentum spread δp=±0.001 over a resonance map up to order 10.*

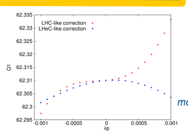


*Figure 3. Tune Q1 vs δp after the chromatic correction*

## DA

**Maximum surviving amplitude**

**Conditions:**

100,000 turns
60 seeds, errors magnets
5 angles,
Resolution 2 Sigma

The LHeC lattice DA with L*=10 m and β*=10 cm has been found and is given in comparison with the HL-LHC nominal lattice in Fig. 3 for different initial angles.

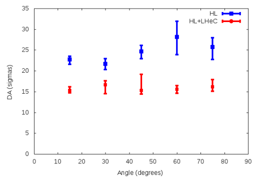


*Figure 4. Dynamic Aperture comparisson between HL and HL+LHeC*

It is observed that there is a reduction of several sigmas in comparisson, specially at high angles, but still above the required minimum for the LHC. Further studies to be done including errors in IT, Q4 and Q5.

Computation of DA for different L*

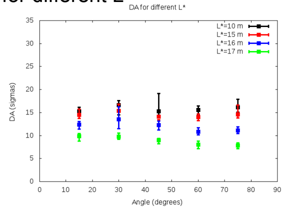


*Figure 5. Dynamic Aperture comparisson between optical designs with different L**

Case with L*=15 m present a reduction In comparisson with L*=10 m but is minimal. More substantial reduction is observed for bigger L*.

## FMA

**Computed tunes after different number of turns. Can provide indication of instabilities.**

**Conditions**

5,000 and 1,000 turns
90 angles
0-22 Sigma, 0.1 resolution.
1 seed

The difussion factor is calculated and plotted for the lattice with L*=10 m in an amplitude map (Fig. 6) and in a resonance map (Fig. 7)

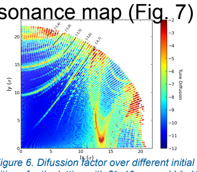

*Figure 6. Difussion factor over different initial conditions for the lattice with β*=10 cm and L*=10 m*

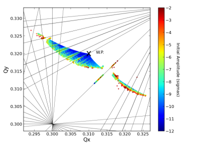

*Figure 7. Difussion factor over a tune map for the lattice with β*=10 cm and L*=10 m*

The amplitude map is compared with the cases with L*=15 m (Fig. 8) and L*=17 m (Fig. 9).

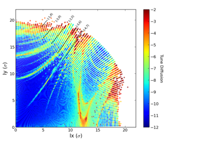

*Figure 8. Difussion factor over different initial conditions for the lattice with β*=10 cm and L*=15 m*

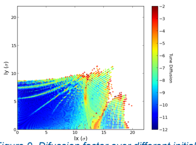

*Figure 9. Difussion factor over different initial conditions for the lattice with β*=10 cm and L*=17 m*

Again, cases with L*=10 m and L*=15 present similar results but changes drastically for the case L*=17 m.

## Conclusions

Tracking studies in terms of the dynamic aperture and frequency map analysis were performed for the cases with L*=10, 15 and 17 m. Similar results were found for the cases L*=10 and 15 with only a small reduction in DA for the case with L*= 15 m. For the case L*=17 m however a bigger reduction was observed in the DA and instabilities are observed in FMA. This results add to the previous studies to show that the cases L*=14 and L*=15 m seem to provide the best design for the LHeC IR.

## References


[1] R. Tomás, "Interaction Region" in the Meeting on LHeC with Daresbury group, September 2012: http://indico.cern.ch/conferenceDisplay.py?confId=207665
[2] M. Korostelev et al., "LHeC IR optics design with integration into the HL-LHC lattice", MOPWO063, IPAC '13 Conference Proceedings.
[3] S. Fartoukh, "Towards the LHC Upgrade using the LHC well-characterized technology," sLHC Project Report 0049.
[4] E. Cruz et al., "LHeC IR optics design integrated into the HL-LHC lattice", THCL1021, IPAC '14 Conference Proceedings.


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